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ORIGINAL RESEARCH

CLINICAL MEASURES OF HIP RANGE OF MOTION DO NOT CORRELATE WITH THE DEGREE OF CAM MORPHOLOGY IN SEMI-ELITE AUSTRALIAN FOOTBALLERS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Clinical testing to determine the presence of a cam morphology is becoming more common however the correlation between hip range of motion and the degree of cam morphology remains controversial in the literature. The prevalence of a cam morphology in athletes has been reported as higher than in the general population but the prevalence of cam morphology has not been reported in Australian Football (AF).

Purpose: The purpose of this study was to determine the correlation between hip range of motion and hip alpha angle and report the proportion of players with a cam morphology in a sample of AF players.

Design: Cross-sectional Study.

Methods: Twenty-one semi-elite AF players (42 hips) from the Peel Thunder Football Club were included in this study. A hip Flexion Internal Rotation (IR) test and a modified maximal squat test using the difference in depth of squat in hip internal and external rotation were used. These measures were then compared to alpha angles on 90 degree Dunn view x-rays.

Results: Four of the 42 hips (9.5%) had a cam morphology (alpha angle >60 degrees). There was no significant correlation between alpha angle and ROM in a Flexion IR test or the difference in modified maximal squat test depth within this sample of players.

Conclusions: The proportion of cam morphology seems to be lower in this sample than the previously reported prevalence in other sports. The lack of correlations between hip range and hip alpha angle in players means that screening hips using clinical measures to detect cam morphology associated with poor hip range of motion may be inaccurate.

Level of Evidence: Level 3a

Key Words: Femoroacetabular impingement syndrome, groin pain, range of motion, screening tests

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INTRODUCTION

Anterior hip and groin pain is highly prevalent within some sporting populations.[1] The hip joint is a possible source of symptoms for athletes who complain of anterior hip and groin pain.[2] Hip related groin pain in young athletes is often attributed to Femoroacetabular Impingement Syndrome (FAIS).[3] Cam morphology is the most common type of FAIS.[3] Cam morphology likely develops during adolescence when the proximal femoral growth plate is open[4] and there is some evidence to suggest this is correlated with training load(s) during this period.[5-7] The implications of these morphologies are still not thoroughly understood, and cam morphology has been proposed as a risk factor of hip osteoarthritis.[8 9]

In the 2013 Australian Football (AF) League season, 1.1 new injuries and 4.6 missed games per club were attributed to hip pathology.[10] These figures decreased in 2014 to 0.3 new injuries and 0.8 missed games per club,[10] and it is suspected that in part this drop is due to better detection and injury prevention programs.[10]

Radiological findings of cam morphology have been reported previously as highly prevalent, with a recent systematic review reporting a prevalence of 5-75% across of variety of clinical populations.[11] The prevalence appears to be specifically high in athletic groups, with cam morphologies evident in 72% of collegiate football players,[12] 68% of elite soccer players[13] and 75% of youth ice hockey players[14] however to date no studies have explored the prevalence of these radiological findings within an AF population. It has also been shown within semi-professional soccer players that the presence of cam morphology differs between the kicking and non-kicking legs[15] however this has yet to be investigated in AF. Finally the prevalence of cam morphology also appears to be significantly related to ethnic backgrounds with white soccer players having a higher proportion of large cam morphology compared to their black counterparts.[16]

Radiological examination is currently used to detect these morphologies[3 17 18] however screening to detect cam morphologies with clinical examination is becoming more common.[19] Cam type morphology has been associated with decreased internal rotation (IR) of the hip[20 21] and correlations between clinical testing of hip IR and the degree of cam morphology as measured by the alpha angle on x-ray have been reported as ranging from -0.35 to -0.59.[22] However, a recent systematic review did not support differences in IR range between people with symptomatic FAIS and asymptomatic controls[23] making uncertain the validity of clinical screening for these morphologies.

A plethora of clinical tests for FAIS were identified in a systematic review by Reiman et al. (2015).[24] The Flexion Adduction Internal Rotation test (FADDIR) was the most commonly studied clinical test with a pooled sensitivity and specificity of 0.94-0.99 and 0.05-0.09[24] respectively, however the FADDIR is a test of pain provocation and does not provide a measure of hip range of motion. The second most commonly studied clinical test was the Flexion IR test with a pooled sensitivity and specificity of 0.96 and 0.25[24] respectively which is not only a test for pain provocation but also provides an objective measuremeant of hip IR. The only functional test identified was a maximal depth bilateral lower extremity squat which was reported by Ayeni et al. (2014)[25] with a sensitivity and specificity of 0.75 and 0.41 respectively.[24] The advantage of the Flexion IR test and the maximal squat test are that they both provide objective measures of range of motion which is important in screening procedures.

The lack of functional tests for FAIS has been previously reported in the literature with a maximal squat test being identified as the only functional test that has demonstrated evidence for use in screening for FAIS.[26] Functional tests play an important role in the assessment of FAIS as FAIS has been shown to alter biomechanics during normal functional tasks such as walking and deep squatting when compared to controls.[27 28] Functional tests help identify these impairments and hence enable clinicians to address them and return the normal function seen in controls.

If a correlation exists between decreased hip ROM and cam morphology, it would be expected that clinical examination of hip range of motion would be correlated with the degree of cam morphology on X-ray. Specifically increases in the alpha angle of the hip joint, which demonstrates the degree of bony cam morphology, should be correlated with a decrease in the hip joint ROM. The purpose of this study was to determine the correlation between hip range of motion and hip alpha angle and report the proportion of players with a cam morphology in a sample of AF players.

METHODS

Study Design

The study was a retrospective cross-sectional design as data collection was planned after both the index and reference tests had been performed.

Data Collection

All data were collected between November 2014 and February 2016 during two consecutive AF club seasons.

Participants

Participants were men competing in the semi-elite level West Australian Football League training three times per week and playing once per week. The sample included athletes with and without anterior hip and groin pain and all athletes who attended pre-season screening were included in the study (Figure 1).

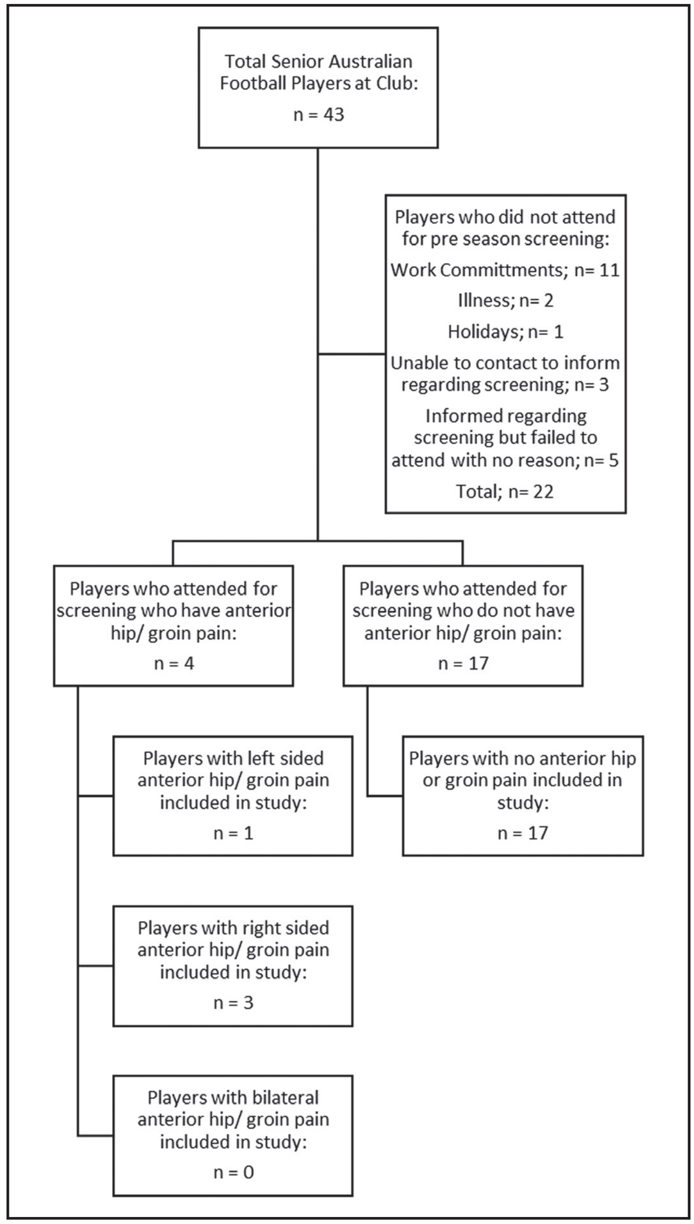

Figure 1. *STARD Flow Chart.*

Outcome Measures

Radiological testing (reference test) and physical testing (index tests) were completed as a part of routine club screening. Index tests were performed first, with the reference test being performed within the two weeks of the index tests. Radiological investigations occurred in a variety of radiological imaging centres by qualified radiographers and all imaging was performed with a standard protocol. Physical examination occurred at the football club in Mandurah by the club's head physiotherapist (MM) who has postgraduate qualifications in sports physiotherapy and four years of experience. The 90 degree Dunn view radiograph was the reference test, with the index tests being the Flexion IR test and modified maximal squat test.

90 Degree Dunn View Radiograph

The reference test was a 90 degree Dunn view radiograph of both hip joints and was chosen due to being a recommended measure of detecting cam morphology.[18] This view has a sensitivity of 91% and specificity of 88% for diagnosing cam morphology and was superior to other radiographs for detecting cam morphology.[17] The 90 degree Dunn view also showed a Pearson's correlation coefficient of 0.702 when compared to MRI in detecting cam morphology, which was superior to an anterior-posterior (AP) pelvis or cross table lateral radiograph.[17] The 90 degree Dunn view x-rays of the hips were taken with the player supine on the table with the hip and knee flexed to 90 degrees and the hip abducted to 20 degrees.[17,18] The cross hairs of the x-ray were directed mid-way between the anterior

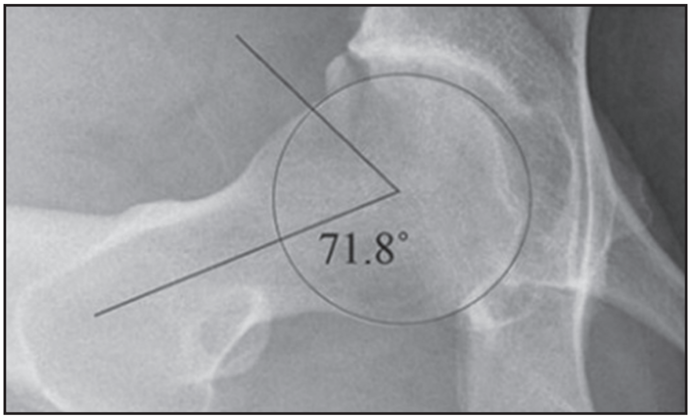

Figure 2. *Alpha Angle from Barton et al. (2011). The first line is drawn from the centre of the femoral head to the point on the anterolateral aspect of the head neck junction, where the radius of the femoral head first becomes greater than the radius found in the acetabulum. The second line is drawn through the centre of the femoral neck connecting to the centre of the femoral head. The alpha angle was determined manually by measuring the angle between the two lines.*

superior iliac spine and pubic symphysis with the x-ray tube to film distance approximately 102cm in a line directed perpendicular to the table.[17 18] The alpha angle was determined manually by measuring the angle between two lines as described by Barton et al. 2011 (Figure 2).[17] The first line was from the centre of the femoral head to the point on the anterolateral aspect of the head neck junction, where the radius of the femoral head first becomes greater than the radius found in the acetabulum.[17] The second line was drawn through the centre of the femoral neck connecting to the centre of the femoral head.[17] All alpha angles were manually calculated by one sports medicine doctor (JC) who was provided de-identified, randomly numbered x-rays to report without access to any clinical details. Intra-rater reliability was evaluated by repeat measure of 20 X-rays with an ICC of 0.89 (95%CI: 0.70-0.96), SEM of 3.8 degrees and MDC of 10.5 degrees (Appendix A).

Players were diagnosed with a Cam morphology if they had an alpha angle of greater than 60 degrees[29] on the 90 degree Dunn view radiograph and the proportion with corresponding 95% confidence interval was determined from the sample.

Flexion and Internal Rotation Test

The Flexion IR test has been previously used to assess the degree of hip internal range of motion in FAIS.[19] [21 22 30] The Flexion IR was performed with the patients supine and the hip and knee passively flexed to 90 degrees before passively internally rotating the hip to end of range ensuring both anterior superior iliac spines (ASIS) remained level[30] (Figure 3) and the location and intensity, on a numerical rating scale, of any pain was recorded. Hip IR was measured in degrees using a standard goniometer. The fixed arm of the goniometer was aligned with the transverse line parallel to the ASIS, the fixed point aligned with the apex of the patella and the mobile arm aligned with the tibial spine.[30] In patients with FAIS, hip IR goniometry measures have been shown to have good validity compared to an electromagnetic tracking system with an intraclass correlation coefficient (ICC) of 0.88 (95% CI 0.50 to 0.96) and an intra-rater reliability ICC of 0.95.[30]

Modified Maximal Squat Test

The modified maximal squat test is a test which involves a functional movement (squatting) in both a position of provocation and ease for participants with FAIS. Given hip flexion and IR is aggravating a squat in more IR was theorized to be more provocative and limiting for participants with FAIS. The test was performed in standing with players directed to stand with the medial aspect of heels 45cm apart adjacent to a fixed line and the posterior heel aligned on another fixed line. The medial aspect of the player's 1st MTP joint was then aligned with a line either 20 degrees internally or externally rotated from the line the medial aspect of the heel was adjacent to. In the positions of 20 degrees internal and external rotation the players were asked to squat as deeply as possible (Figure 4) and a line was measured (cm) between the inferior aspect of the posterior superior iliac spine and the floor on both sides and then repeated three times. The mean squat depth in IR was then subtracted from the mean squat depth in external rotation to get the difference in squat depth. Intra-rater reliability was evaluated by repeat measure of 20 players three days following with an absolute ICC of 0.88 (95% CI: 0.73-0.95), SEM of 3.3cm and MDC of 9.1cm (Appendix A).

Ethics Statement

This study was approved by the Human Research Ethics Committee at Curtin University in Western Australia, Australia with the following approval number:

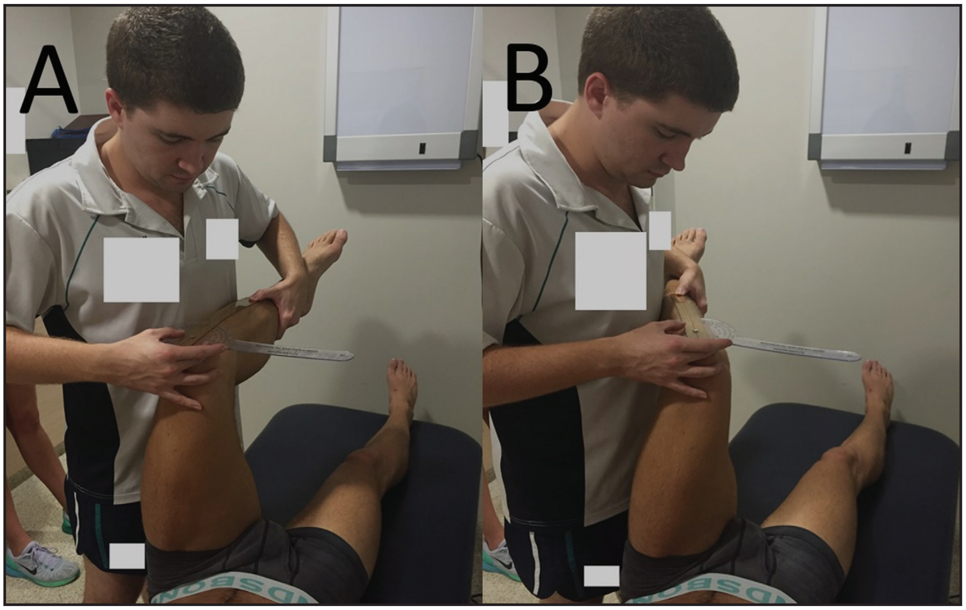

Figure 3. *Hip Goniometry in 90 degrees flexion (**A.** Hip in a neutral position and **B.** Hip in maximal internal rotation).*

Figure 4. *Modified Maximal Squat Test (**A.** Hip in 20 degrees external rotation and **B.** Hip in 20 degrees internal rotation).*

RDHS-205-15 and the subjects gave informed consent to the work. The declaration of Helsinki was followed and the rights of the players were protected.

Power Calculation

Power calculations for Pearson's and Spearman's correlations were performed with power set at 0.8 and significance set at 0.05. It was determined that to detect a correlation of 0.44, which has what has previously been demonstrated as the correlation between the hip alpha angle and a flexion IR test by Kapron et al. 2012 in collegiate football, that a sample of 38 hips were required.

Statistical Analysis

The mean of the left and right alpha angles, the mean of the left and right Flexion IR tests and the mean of the left and right maximal squat depth difference were determined. Statistical significance between sides of all participants and between asymptomatic and symptomatic sides of participants with symptoms were determined using unpaired t-tests. The correlation between the left and right alpha angles, the correlation between the left and right Flexion IR tests and the correlation between the left and right maximal squat depth difference were determined using Pearson's correlation coefficients and corresponding 95% confidence interval. Finally, the correlation of the index tests and the reference tests was determined using Spearman's correlation co-efficient, corresponding 95% confidence interval and statistical significance was determined. Statistical significance was set at 0.05. Data were analysed using IBM SPSS Statistics 22.0 (Chicago, USA).

RESULTS

Demographics

Participants were a mean of 21.1 (+/- 2.5) years old; 184 (+/- 7.4) cm tall; 78.1 (+/- 5.1) kg in weight, and had a mean BMI of 23.1 (+/- 1.2) kg/m².

Proportion of Players with Cam Morphology

Four of the 42 hips had a cam morphology with two players having bilateral cam morphology and no players having a unilateral cam morphology. Hence the proportion of hips in this sample with cam morphology was 9.5% (95% CI 3.8 to 22.1).

Differences between Index and Reference Tests between sides

The mean measurements for the alpha angle, flexion IR test ROM, and difference in modified maximal squat test depth of the entire sample are presented in Table 1. No significant differences were detected between sides.

The symptomatic players mean data for the alpha angle, flexion IR test ROM, difference in modified maximal squat test depth are presented in Table 2. No significant differences were detected between sides.

Correlation between Index and Reference Tests

Pearson's *r* (95% CI) correlations between left and right hip measurements were $r = 0.81$ (0.59 to 0.92) for Flexion IR; $r = 1.00$ (0.99 to 1.00) for maximal squat difference; and $r = 0.98$, (0.94 to 0.99) for alpha angles. The Spearman's rho (95% CI, p) between the Flexion IR and alpha angles (n = 42) was 0.15 (-0.16 to 0.43, p = 0.36) and is shown in Figure 5. After the removal of the players with cam morphology (n = 38) the adjusted Spearman's correlation co-efficient was 0.48 (0.19 to 0.69, p = 0.002). The Spearman's rho (95% CI, p) between the modified maximal squat test depth difference and alpha angles (n = 42) was -0.25 (-0.51 to 0.06, p = 0.11) and is shown in Figure 6. After the removal of the players

Table 1. *Index and Reference Tests.*

	Number of players	Left mean(SD)	Right mean(SD)	Unpaired t-test (p-value)
Alpha Angle (degrees)	21	48.4 (11.6)	49.4 (10.3)	0.77
Flexion IR Test (degrees)	21	23.1 (11.5)	24.6 (11.1)	0.69
Modified Maximal Squat Depth (cm)	21	27.3 (14.1)	27.4 (14.1)	0.97

IR= internal rotation

Table 2. *Symptomatic Players Index and Reference Tests.*

	Number of players	Symptomatic mean(SD)	Asymptomatic mean(SD)	Unpaired t-test (p-value)
Alpha Angle (degrees)	4	50.0 (14.2)	48.8 (15.4)	0.91
Flexion IR Test (degrees)	4	14.2 (9.3)	25.2 (11.4)	0.18
Modified Maximal Squat Depth (cm)	4	22.2 (5.3)	23.2 (5.6)	0.80

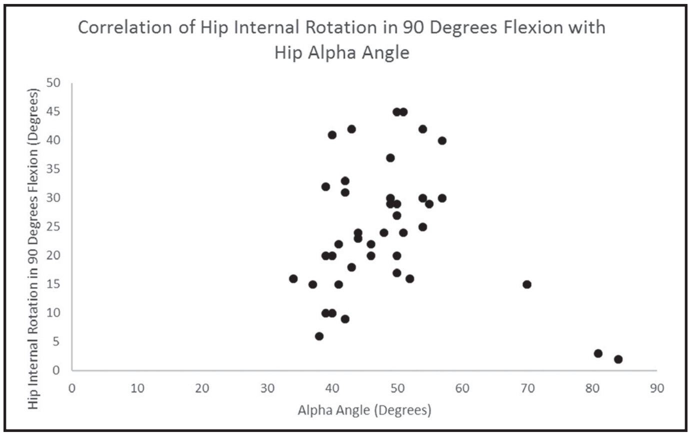

Figure 5. *Correlation of Hip Internal Rotation in 90 Degrees Flexion with Hip Alpha Angle.*

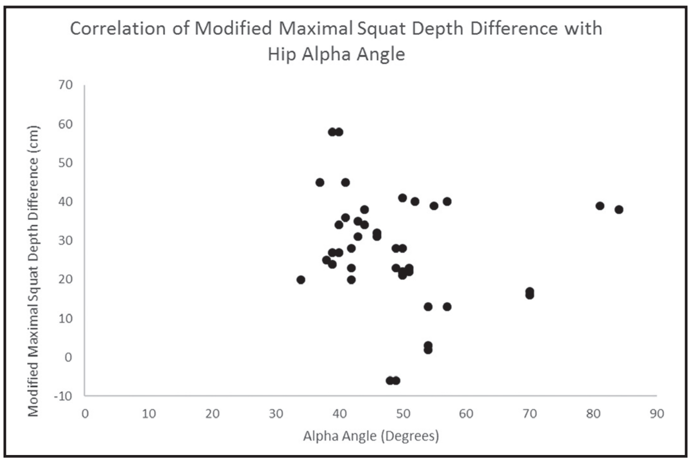

Figure 6. *Correlation of Modified Maximal Squat Depth Difference with Hip Alpha Angle.*

with cam morphology (n=38) the adjusted Spearman's correlation co-efficient was -0.30 (-0.56 to 0.02, p=0.07).

DISCUSSION

This study aimed to examine the relationship between cam morphology and clinical tests as well as to determine the proportion of AF players with cam morphology. The prevalence of cam morphology was 9.5%, with no significant correlation between the size of cam morphology and performance on clinical tests.

Strong correlations were found when comparing the results of index and reference tests against themselves from left to right with no statistically significant differences between sides. The findings in the study differ with those reported previously in semi-professional soccer players, where some players had unilateral cam morphology.[15] This suggests that within AF players, differences between cam morphology on the kicking and non-kicking leg are less common. These differences may be due to the variations in training load with differences in the proportion of kicking on the dominant and non-dominant legs during adolescence.[4-6]

When comparing the symptomatic and asymptomatic sides there was no significant difference between groups which supports the results presented in the systematic review by Freke et al. 2016.[23] However, there was a non-significant trend towards decreased hip IR on the symptomatic side, independent of the alpha angle, which has been reported previously by Tak et al. 2016 in professional soccer players.[31] While not statistically significant having a mean difference of 11 degrees between symptomatic and non-symptomatic sides may be considered clinically significant. This difference may have become more apparent and been considered statistically significant if the sample had a higher proportion of athletes with anterior hip and groin pain and this is a limitation of the current study.

The results of this study failed to show a significant correlation between the alpha angle on radiographs and the degree of hip rotation in a Flexion IR test or mean difference in squat depth. Positive correlations existed between hip IR during a flexion IR test when compared to the alpha angle, but only after the removal of hips with cam morphology. These findings suggest that in players without cam morphology greater hip IR correlated to higher alpha angles. There was no correlation between the maximal squat test difference when compared to the alpha angle, even after the removal of hips with cam morphology. This lack of correlation further supports that cam morphology is not associated with a reduction in hip joint range of motion.[23] It may also be possible that a non-linear relationship exists between clinical measures of hip range of motion and cam morphology, as cam morphology has been shown to have a binomial distribution.[29] However, as only four hips had a cam morphology in this study, it was not possible to evaluate this supposition, and larger cohort studies are needed to investigate this further.

This study reported the proportion of hips with cam morphology within a sample of semi-elite AF players as 9.5% which sits inside the range reported in the systematic review by Dickenson et al. 2016.[11] Interestingly however, the proportion of hips with cam type morphology observed using radiographs was substantially lower within this sample of AF players than what has previously been reported in other athletic populations such as collegiate football,[12] soccer[13] and ice hockey.[14] These differences may, in part, be explained by a different alpha angle considered diagnostic of cam morphology as this study used an alpha angle of 60 degrees which is higher than other studies which have used alpha angles of 50-55 degrees.[12-14] The justification for the use of an alpha angle of 60 degrees is Agricola et al. (2014) found a definite binomial distribution of the alpha angle, within two cohorts (n = 1002 and n = 1003 respectively), with a normal distribution up to 60 degrees indicating a clear distinction between normal and abnormal alpha angles.[29] Large reductions in the prevalence can be observed with one study showing a reduction in the prevalence of cam deformity from 92% to 46% by changing the alpha angle cut off from 50 to 60 degrees.[32] It has been shown that even by increasing the alpha angle cut-off from just 55 to 60 degrees a marked reduction in the prevalence of cam morphology from 30-61% to 17-47% is seen.[33] A further reason for a smaller proportion of cam morphology in this sample may relate to only performing a single view radiograph, and including an AP radiograph may capture cam morphology in more participants.[21] The smaller proportion of players with cam morphology within this sample may also relate to players having a lower frequency of training due to the current practices of Australian Football if a relationship between training and the development of cam morphology truly exists.[5 6] Based on current training practices the players in this sample likely trained less than/ equal to three sessions per week before 12 years of age which may decrease the likelihood of developing a cam morphology.[6]

Finally, the small proportion of players with cam morphology may relate to small sample size and larger, prospective studies including more clubs are needed in this area to more realistically measure the prevalence of cam morphology within AF players. Larger, prospective studies are also needed to investigate the relationship between range of motion and structure to help inform clinicians on the validity of clinical assessment to the degree of cam deformity.

CONCLUSION

Hip IR range of motion and differences in squat depth performance tests did not correlate to the degree of cam deformity in AF players however further research is needed in a sample with a larger prevalence of cam morphologies to determine the role of functional testing in the diagnosis and management of athletes with FAIS. The proportion of cam morphology in this sample of semi-elite AF players was significantly lower than other sports.

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